APPARATUS HAVING PLATFORMS POSITIONED FOR PRECISE CENTERING OF SEMICONDUCTOR WAFERS DURING PROCESSING

Field of the Invention

This invention relates to an apparatus ensuring the accurate placement of semiconductor wafers onto respective platforms (or susceptors) within reaction chambers which are precisely (and adjustably) spaced apart, the apparatus providing compensation for dimensional variations due to mechanical tolerances and reducing the effects of thermal expansion or contraction with changes in temperature.

Background of the Invention

Today's semiconductor circuits have features such as vias with diameters that are a small fraction of a micron, for example, only about 0.13 micron, with depths of 4 to 5 times the diameter. Such small via diameters and large depth to diameter ratios make it difficult with currently used materials (e.g., aluminum or copper) to properly metalize the vias completely down to their lower ends. Accordingly, a chemical vapor metalizing process using a highly volatile precursor compound of tungsten, such as tungsten hexaflouride (WF_6), is advantageously used to metalize the vias. In order to keep the tungsten being deposited on the exposed surface of the wafer from being deposited beyond and/or beneath the edge or rim of the wafer, inert gas, such as argon or argon mixed with helium, is flowed in an annular stream of the gas upward and over the rim. Flowing such a stream of inert gas, termed "edge-purging", reduces or eliminates tungsten deposition adjacent the edge of the wafer by diluting or physically excluding the WF_6 precursor gas. For edge-purging to be fully effective, however, each wafer should be accurately centered on its respective platform.

In order to increase manufacturing throughput for a given capital investment, two wafer platforms can be mounted in a processing chamber. However, with previously known apparatus the exact positions of the centers of the platforms can vary because of manufacturing tolerances or

because of thermal expansion or contraction of the apparatus caused in turn by changes of temperature. Unless these dimensional variations are properly compensated for they can significantly affect the efficiency of edge-purging because of inaccurate centering of the wafers when placed on their respective platforms. The present invention provides a simple and effective way of overcoming these difficulties.

Summary of the Invention

In accordance with the invention, in one specific aspect thereof, there is provided an apparatus for processing semiconductor wafers. The apparatus provides for accurate placement of two or more wafers onto respective processing platforms by substantially reducing mechanical tolerance and other variations in the positions of the platforms relative to that of a wafer-handling robot.

(Claim 1) From a first apparatus aspect, the present invention is an apparatus for processing multiple semiconductor wafers. The apparatus comprises a transfer chamber, first and second processing chamber, and a robot. The first processing chamber is mounted in fixed relation to the transfer chamber and has a first wafer-holding platform with a center. The second processing chamber is mounted in adjustable relation to the transfer chamber and to the master chamber and has a second wafer-holding platform with a center. The robot is rotatably mounted within the transfer chamber and has first and second wafer-holding arms spaced parallel to each other for inserting a pair of wafers simultaneously into the first and second chambers and for placing the wafers accurately centered over the respective platforms. The spacing of the platform centers is adjusted relative to the spacing of the robot arms such that the wafers are centered and placed with a preselected degree of accuracy onto the respective platforms for efficient processing of the wafers.

(Claim 3) From a second apparatus aspect, the invention is an apparatus for processing multiple

semiconductor wafers. The apparatus comprises a transfer chamber, first and second processing chamber, a mechanism for adjustably mounting the second chamber in relation to the first chamber and to the transfer chamber, and a robot. The first processing chamber is mounted in known relation to the transfer chamber and has a first wafer-holding platform with a center. The second processing chamber has a second wafer-holding platform with a center. The mechanism provides a plurality of position adjustments for the second chambers. The robot is rotatably mounted within the transfer chamber and has first and second wafer-holding arms spaced parallel to each other for inserting a pair of wafers simultaneously into the first and second chambers and for placing the wafers accurately centered over the respective platforms. The spacing of the platform centers are adjusted relative to the spacing of the robot arms such that the wafers are centered and placed with a preselected degree of accuracy onto the respective platforms for efficient processing of the wafers.

(Claim 7) From a third aspect the invention is an apparatus for processing at least two semiconductor wafers simultaneously. The apparatus comprises a transfer chamber, a load-lock chamber adjacent the transfer chamber, first and second processing chambers, adjusting means for adjustably mounting the second chamber in relation to the first chamber and to the transfer chamber, and a robot. The first processing chamber is mounted in known relation to the transfer chamber and has a first wafer-holding platform with a center. The second processing chamber has a second wafer-holding platform with a center. The adjusting means has a bellows assembly positioned between the transfer chamber and the second chamber and provides for relative movement thereof and also provides a wafer passageway between the chambers while maintaining an hermetic seal. The robot is rotatably mounted around a center axis within the transfer chamber and has first and second wafer-holding arms spaced parallel to each other for withdrawing a pair of wafers from the load-lock chamber and

inserting the pair of wafers simultaneously into the first and second chambers and for positioning both of the wafers with a preselected degree of accuracy over the respective platforms. The spacing of the platform centers is adjusted to a preselected degree of accuracy by the adjusting means relative to each other and to the spacing of the robot arms and the center axis such that the wafers are centered and placed with the preselected degree of accuracy onto the respective platforms for efficient processing of the wafers.

(Claim 9) From a fourth aspect the invention is an apparatus for processing a pair of semiconductor wafers simultaneously. The apparatus comprises a transfer chamber, a load-lock chamber adjacent the transfer chamber, first and second processing chambers, mechanical means for adjustably mounting the second chamber in relation to the first chamber and to the transfer chamber, mechanical means for adjustably mounting the second chamber in relation to the first chamber and to the transfer chamber, a slit valve, and a remotely controlled robot. The first processing chamber is mounted in fixed relation to the transfer chamber and has a first wafer-holding platform with a center. The second processing chamber has a second wafer-holding platform with a center. The mechanical means supports the second chamber against the load-lock chamber in cantilever fashion and has a bellows assembly positioned between the transfer chamber and the second chamber to provide for relative movement thereof and to provide a wafer passageway between the respective chambers while maintaining an hermetic seal. The remotely controlled robot is rotatably mounted around a center axis within the transfer chamber and has first and second wafer-holding arms spaced parallel to each other for withdrawing a pair of wafers from the load-lock chamber and inserting the pair of wafers simultaneously into the first and second chambers and for positioning both of the wafers to a preselected degree of accuracy over the respective platforms. The spacing of the platform centers are adjusted by the

mechanical means relative to each other and to the spacing of the robot arms and the center axis such that the wafers are centered and placed with the preselected degree of accuracy onto the respective platforms for efficient processing of the wafers.

A better understanding of the invention will be gained from the following description given in conjunction with the accompanying drawings and claims.

Brief Description of the Drawings

FIG. 1 is a schematic plan view, partially broken away, showing portions of an apparatus embodying features of the invention with dual chambers (one fixed and the other adjustable) for accurately processing semiconductor wafers;

FIG. 2 is an exploded view in perspective showing a mechanism provided according to the invention for positioning the center of one of the dual chambers with great accuracy relative to the other and to a wafer-handling robot;

FIG. 3 is a side section view taken as indicated by a line 3-3 in FIG. 1, showing the mechanism of FIG. 2 adjustably coupling one of the chambers of FIG. 1 to a fixed portion of the apparatus;

FIG. 4 is a schematic plan view of a portion of the mechanism of FIG. 2 illustrating how a bellows (a central part of the mechanism) can be expanded or contracted to adjust the longitudinal position of the one chamber;

FIG. 5 is a schematic plan view of the bellows of FIG. 2 illustrating how the bellows can be compressed at either end to adjust the sideways position of the one chamber; and

FIG. 6 is a schematic side view of the bellows of FIG. 2 showing how the bellows can be compressed lengthwise along an edge to adjust the vertical position of the chamber.

Detailed Description

Referring now to FIG. 1, there is shown a schematic plan view of an apparatus 10 embodying features of the invention, for accurately processing two or more

semiconductor wafers simultaneously. The apparatus 10 comprises a transfer chamber 12, a wafer-handling robot 14, a first wafer-processing chamber 16, a second wafer-processing chamber 18, a load-lock chamber 20 (shown in dashed outline), and additional wafer-processing chambers 16a, 18a, 16b, and 18b (all shown in dashed outline) which may be identical to the respective chambers 16 and 18.

The chamber 16 is attached in fixed relation to an outer side of a wall 22 (one of four) of the transfer chamber 12. The chamber 18, on the other hand, is attached to the wall 22 by a mechanism, indicated at 24, provided by the invention and which permits the chamber to be adjusted in position in the "X", "Y" and "Z" directions relative to the transfer chamber 12, and to the robot 14. The mechanisms 24 will be described in detail hereinafter.

The chamber 16, which for convenience is termed the "master" chamber, contains a wafer-supporting platform 26 (shown as a dashed line circle) with a center at 28, and the chamber 18, termed the "slave" platform, contains a wafer-supporting platform 30 (shown as a dashed line circle) with a center at 32. The mechanism 24 permits precise adjustment of the slave chamber 18 and the exact position of the platform center 32 by a small angle indicated at 34 lying in a horizontal plane (i.e., the plane of FIG. 1) and by a small amount longitudinally, indicated by an arrow 36 lying within the horizontal plane. As will be explained hereinafter, the position of the slave chamber 18 may also be adjusted slightly in the vertical direction. Thus, the exact position in the "X", "Y", and "Z" directions of the platform center 32 can be precisely set relative to the position of the platform center 28 and the robot 14. Except for their different modes of attachment to the wall 22 of the transfer chamber 12, the master and slave chambers 16 and 18 may be identical to each other.

The robot 14 (well known in the art) has a first horizontal arm 40 which at its outer end holds in precise alignment on the arm a semiconductor wafer 42 having a

center 44. The robot 14 also has a second horizontal arm 46 which holds a second wafer 48 with its center 50 precisely aligned on the arm. As shown in FIG. 1 the robot arms 40 and 46 lie on and are extendable along respective longitudinal, parallel axes 52 and 54. The axis 52 intersects the platform center 28 and the wafer center 44. Similarly, the axis 54 intersects the platform center 32 (the position of this center having been adjusted accordingly) and the center 50 of the wafer 48. Thus when the robot arms 40 and 46 are extended to insert the wafers 42 and 48 into the respective chambers 16 and 18 and onto the platforms 26 and 30, the center 44 of the wafer 42 will be exactly aligned over the center 28 of the platform 26, and the center 50 of the wafer 48 will be exactly aligned over the center 32 of the platform 30.

After having determined the angular and longitudinal coordinates of the center 28 of the platform 26 relative to the center axis 56 of the robot 14, which coordinates can be measured with great accuracy, these values are entered as data in a computer (not shown but well known in the art) which controls the robot. Thereafter, whenever the robot 14 is extended, its arm 40 inserts a wafer into the master chamber 16, and that wafer (i.e., the wafer 42) will be positioned over the platform 26 so that the platform center 28 and the wafer center 44 are exactly aligned. Also, by virtue of the present invention, the other arm 46 of the robot 14, which is simultaneously extended into the slave chamber 18, positions the respective wafer 48 so that its center 50 is exactly aligned with the center 32 of the platform 30.

The robot 14 is rotatable around a vertical center 56 within the transfer chamber 12 so that pairs of wafers can be inserted into or withdrawn from the respective processing chambers and/or the load-lock chamber. The wafers are precisely positioned on their respective robot arms 40 and 46. The transfer chamber 12 is hermetically sealable by a respective pair of slit valves 60 in each of the walls of the chamber. These valves 60 are remotely

operated in conjunction with the robot 14 to permit its arms 40 and 46 to be inserted into selected ones of the load-lock and processing chambers. Some portions of the apparatus 10 (which are well known) are not shown herein. The general construction and operation of the apparatus 10 may be like that shown in U.S. Patent No. 5,855,681, which is incorporated herein by reference.

Referring now to FIG. 2, there is shown in exploded relation the mechanism 24 provided in accordance with the invention for adjusting to a preselected degree of accuracy the position of the slave chamber 18 and the center 32 of its platform 30 relative to the center 28 of platform 26 and to the robot 14. The mechanism 24 comprises a front plate 64, a center bellows assembly 66, a rear plate 68, a pair of springs 70 (only one is shown), set screws 72 (only one of which is shown), and fastening bolts 74 (only one of which is shown). The bellows assembly 66 comprises a front flange 76, a rear flange 78, and an accordion-pleated, thin metal bellows 80 (shown here in dashed line) sealed between the front and rear flanges. The flanges 76 and 78 are fastened and sealed to the respective plates 64 and 68 and provide an hermetic seal around a horizontal passage, indicated at 82, through the plates 64 and 68 via which passage a wafer may be inserted into the slave chamber 18. The bellows assembly 66, while maintaining hermetic seal, permits movement of the front plate 64 relative to the rear fixed plate 68, and thus adjustment of the exact position of the slave chamber 18, as will further be explained shortly. The top of the front plate 64 has a rear shoulder 84, which when the mechanism 24 is fastened together, hooks over and bears down upon a top ledge 86 on the rear plate 68.

Referring next to FIG. 3, there is shown a cross-section taken generally along the line 3-3 in FIG. 1, with portions broken away, showing schematically the mechanism 24 as fastened between the transfer chamber 12 and the slave chamber 18. The transfer chamber 12 (as illustrated here but not FIG. 1) has a top lid 90, and the slave

chamber 18 has a top lid 92 and a wall 94 with the wafer passage-way 82 extending through it. The transfer chamber 12 is hermetically sealable from the slave chamber 18 by a respective slit valve 60 (shown schematically). The plate 68 of the mechanism 24 is fastened and sealed in fixed relation to the wall 22 of the transfer chamber 12 by bolts and hermetic seals (not otherwise identified). Similarly the plate 64 of the mechanism 24 is fastened and sealed in fixed relation to the wall 94 of the slave chamber 18 by bolts and hermetic seals (not otherwise identified). Lastly, the bellows assembly 66, with its front and rear flanges 76 and 78 and bellows 80, is fastened and hermetically sealed between the plates 64 and 68 by bolts and sealing rings (not otherwise identified). Thus the wafer passage-way 82 is hermetically sealed against gas leakage into or out of it even though the plate 64 is moveable relative to the plate 68.

As is shown in FIG. 3, the plate 64 has its top shoulder 84 overhanging the top ledge 86 of the plate 68. Fastened by screws 95 beneath the shoulder 84 is a longitudinal member 96 which rests on the ledge 86 along a horizontal bearing line indicated at 98. The plate 64, along with the slave chamber 18, hangs on the plate 68, being, in effect, hinged to it along the bearing line 98. The ledge 86 has a front step 100 which prevents the member 96 from falling off of the ledge 86. As will be explained in greater detail shortly, by incrementally expanding or contracting the bellows 80, the slave chamber 18 can be adjusted in the "X", "Y" and "Z" directions relative to the master chamber 16 (see FIG. 1) and to the transfer chamber 12 and the robot 14. The "Z" direction may be represented by an arc 102 illustrated in FIG. 3, the arc 102 indicating a slight amount of swinging of the plate 64 toward or away from the plate 68 during adjustment of the position of the slave chamber 18. Movement along the arc 102 (i.e., the "Z" direction) permits the slave chamber 18 to be leveled and to lie in the same horizontal plane as the master chamber 16.

Positioned near the two lower corners of the plates 64 and 68 are respective ones of the compression springs 70 (see also FIG. 2). One of these springs 70 is shown in dotted outline in FIG. 3 and is positioned within a cavity 104 in the plate 64. A plug 106 screwed through the plate 68 compresses the spring 70 by a desired amount to counterbalance the weight of the slave chamber 18. An identical plug 106 and spring 70 (not shown) near the opposite corner of the plates 64 and 68 are adjusted so that both springs 70 exert the same balancing forces against the plate 64.

Positioned near each spring 70 is a respective one of the set screws 72 (also see FIG. 2). One of these screws 72 is adjusted to bear against the plate 64 so that a desired gap indicated at 108, between the plates 64 and 68 is established adjacent a corner of the plates. A similar gap (not shown and not necessarily the same width) is likewise established by another set screw 72 (not shown) at the opposite corner of the plates 64 and 68. The settings of the various set screws 72 establishes the "X", "Y", and "Z" dimensional adjustments of the position of the slave chamber 18. After the set screws 72 have been adjusted, to desired settings, respective ones of the fastening bolts 74, one of which is shown in dotted outline in FIG. 3, are tightened and the plate 64 held immobile relative to the plate 68, so that the dimensional adjustments described above remain intact.

Referring now to FIG. 4 there is shown a plan view schematically illustrating how the mechanism 24 with its bellows 80 can be expanded or contracted, as indicated by the double-headed arrow 36 (see also FIG. 1) to provide dimensional adjustment of what may be conveniently termed the "Y" position of the slave chamber 18. Here the plates 64, 68 are illustrated as parallel to each other.

Referring now to FIG. 5, there is shown a plan view schematically illustrating how the mechanism 24 with its bellows 80 can be compressed on either end (the right end shown compressed here). This provides for relative angular

movement of the plates 64, 68 as indicated by the arc 34 (see also FIG. 1). This movement may be conveniently termed an adjustment in the "X" position of the slave chamber 18.

Referring now to FIG. 6, there is shown a side view schematically illustrating how the mechanism 24 with its bellows 80 can be compressed along its length (the length along the bottom of the bellows 80 being shown as compressed here). This provides for relative angular movement of the plates 64, 68 as indicated by the arc 102 (see also FIG. 3). This movement may be conveniently termed adjustment in the "Z" position of the slave chamber 18.

An apparatus 10, with it mechanism 24 and master and slave chambers 16 and 18, has been built and shown to provide a suitably high degree of accuracy in the centering of semiconductor wafers during processing employing "edge purging". The chambers 16 and 18 easily accommodated wafers of 200 mm size. The slave chamber 18 was adjustable in position by about one-eighth inch (0.125 in.) in each of the "X", "Y" and "Z" directions. Being physically separate units, the chambers 16 and 18 had respective platform centers not appreciably affected by relative thermal expansion, contrary to the case with a single chamber having dual wafer platforms (as known in prior art).

The above description is intended in illustration and not in limitation of the invention. Various changes and modifications in the embodiment illustrated may occur to those skilled in the art and can be made without departing from the spirit or scope of the invention as set forth in the accompanying claims. For example, wafers of different sizes from that given may be processed in the apparatus 10, and the position adjustments of the slave chamber 18 may be different from those given.